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GB 2277219 A GB 2161340 A GB 1571043 A

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(54) **Laser range finders**

(57) A method of selecting a pulse reflected from a target object from a series of pulses including pulses reflected from clutter objects. Where aiming of the source light beam is accurate, and/or the target large, the last received pulse which exceeds a predetermined fraction of the maximum pulse amplitude is selected whilst, where aiming of the light beam is poor, and/or the target small, the first pulse which exceeds said predetermined fraction is selected. In the armoured vehicle system shown, each reflected pulse, after atmospheric compensation at 11, causes the times from clock 15 at which successive thresholds 13 are exceeded to be stored at 14. Microprocessor 16 identifies for each pulse the time corresponding to the highest threshold exceeded, and in accordance with whether anti-personnel or anti-vehicle ammunition is employed (and possibly the range band) selects the first or last such time for range determination.

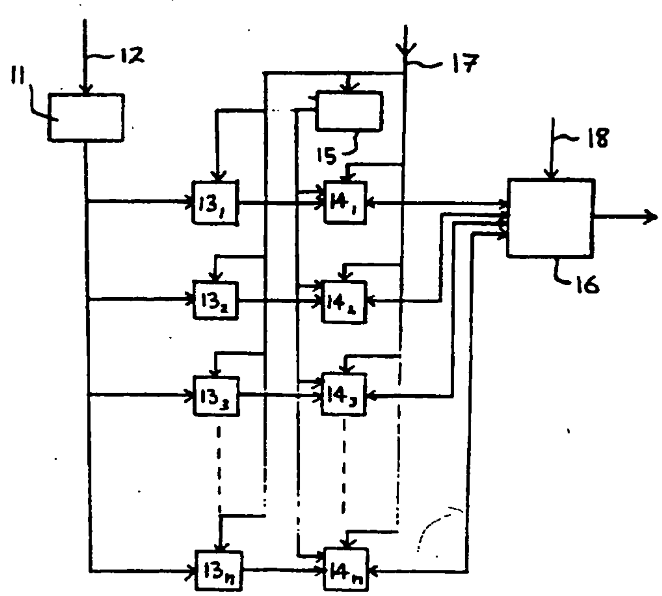

FIGURE 3

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

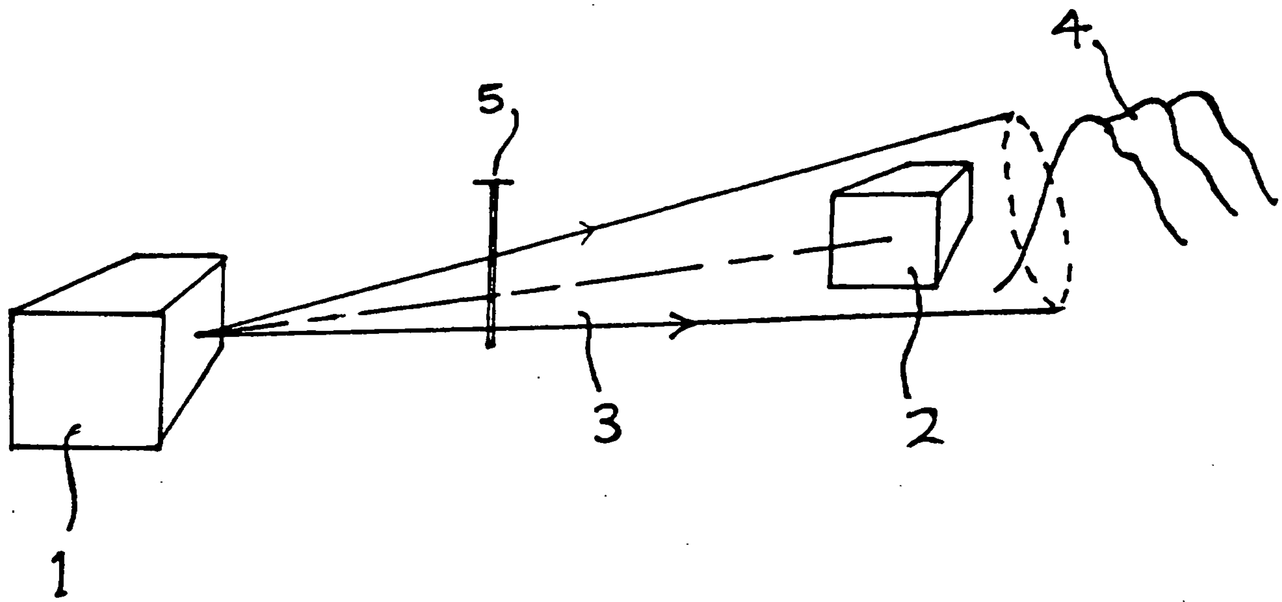

FIGURE 1

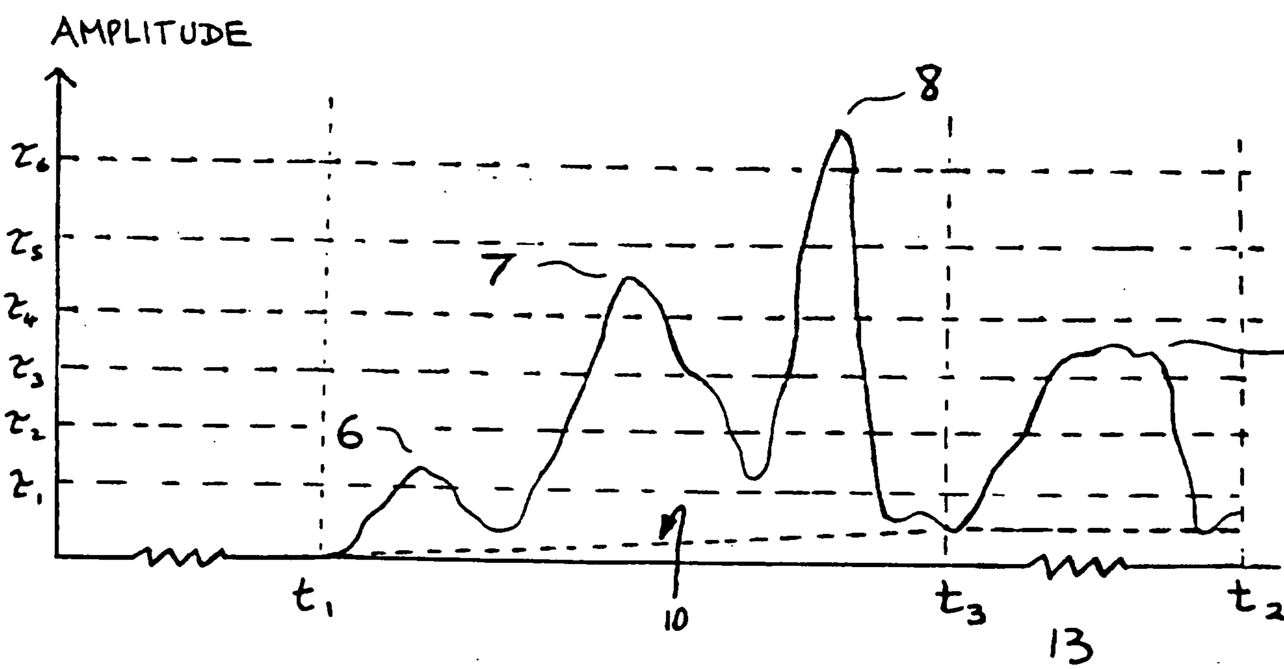

FIGURE 2

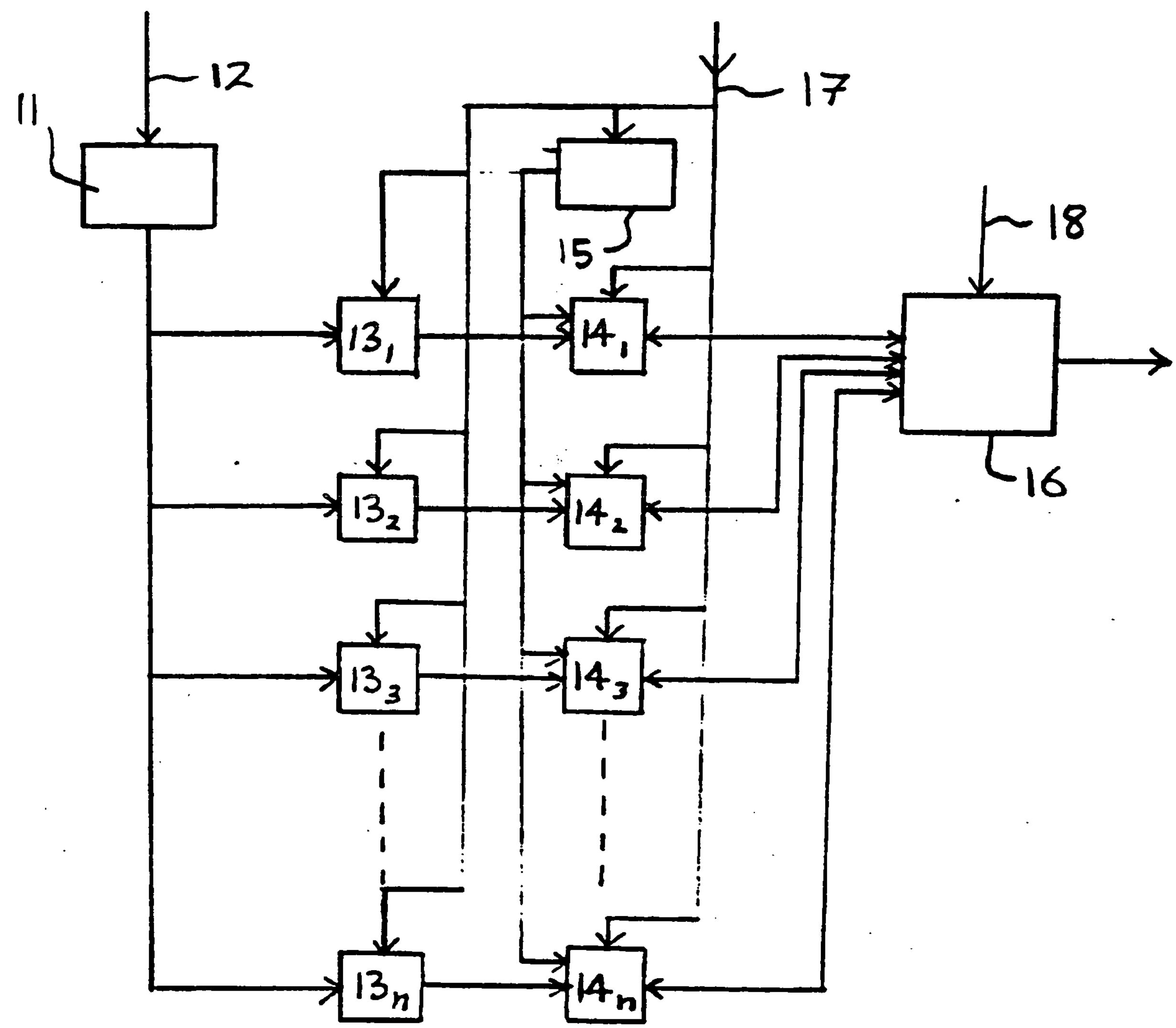

FIGURE 3

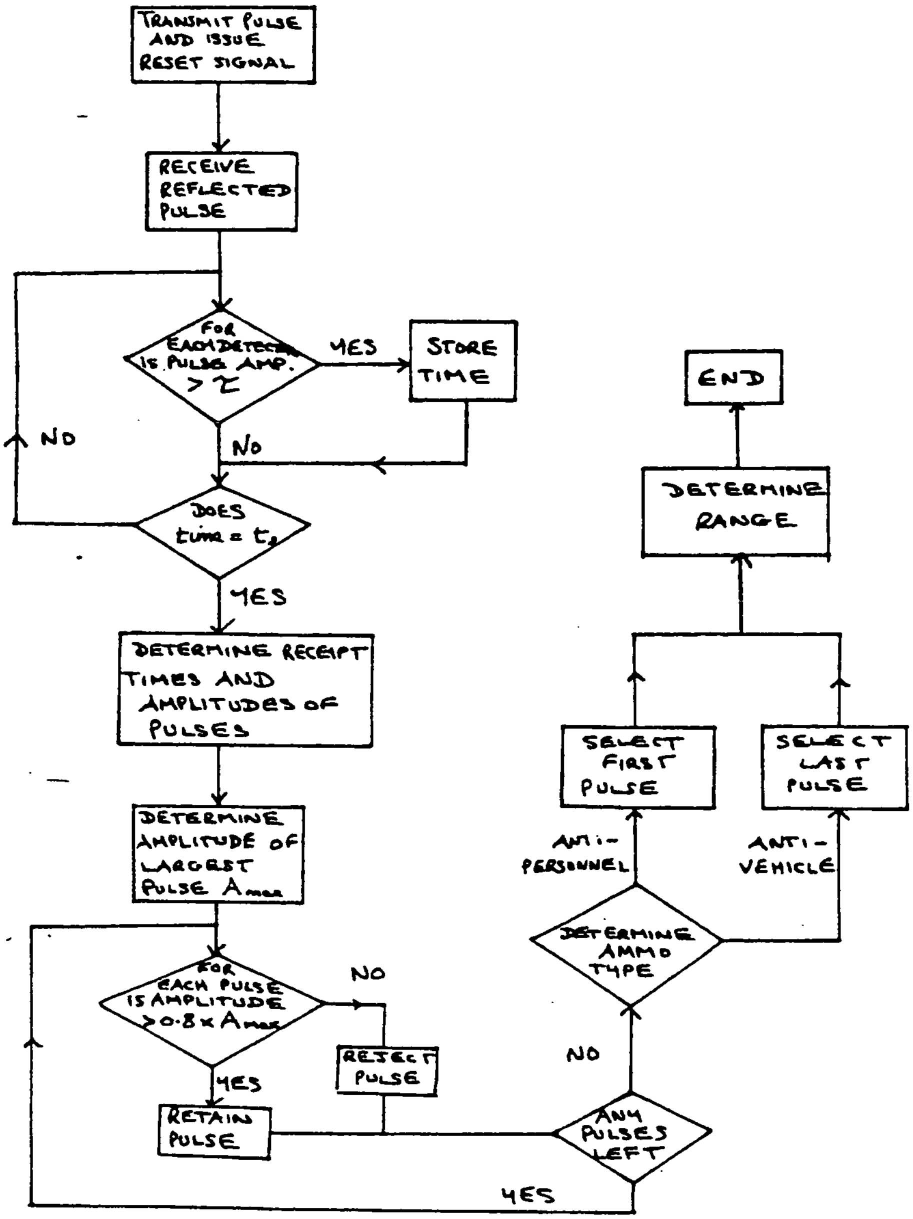
TRANSMIT PULSE AND ISSUE RESET SIGNAL
RECEIVE REFLECTED PULSE
FOR EACH DETECTOR IS PULSE AMP. > τ
YES
STORE TIME
NO
NO
DOES time = t₀
YES
DETERMINE RECEIPT TIMES AND AMPLITUDES OF PULSES
DETERMINE AMPLITUDE OF LARGEST PULSE Amax
FOR EACH PULSE IS AMPLITUDE > 0.8 x Amax
NO
REJECT PULSE
YES
RETAIN PULSE
ANY PULSES LEFT
YES
NO
DETERMINE AMMO TYPE
ANTI-PERSONNEL
ANTI-VEHICLE
SELECT FIRST PULSE
SELECT LAST PULSE
DETERMINE RANGE
END

FIGURE 4

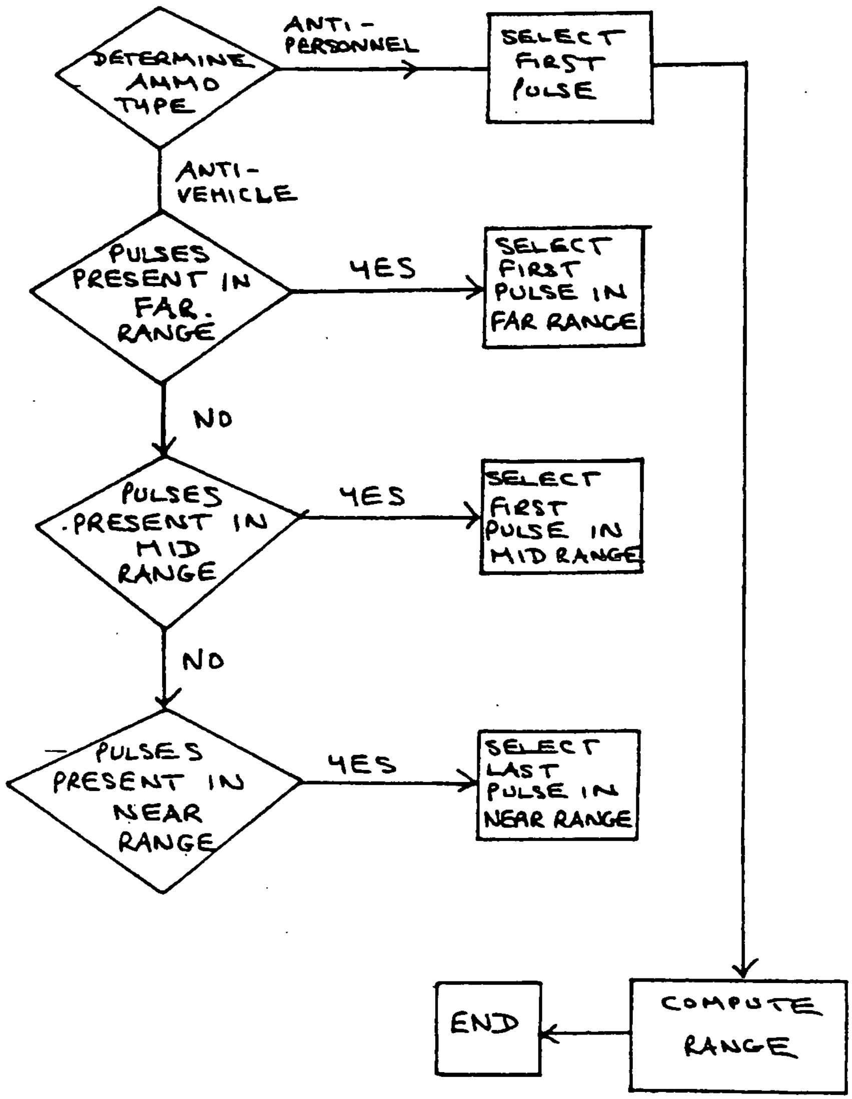
DETERMINE AMMO TYPE
ANTI-PERSONNEL
SELECT FIRST PULSE
ANTI-VEHICLE
PULSES PRESENT IN FAR RANGE
YES
SELECT FIRST PULSE IN FAR RANGE
NO
PULSES PRESENT IN MID RANGE
YES
SELECT FIRST PULSE IN MID RANGE
NO
PULSES PRESENT IN NEAR RANGE
YES
SELECT LAST PULSE IN NEAR RANGE
COMPUTE RANGE
END

FIGURE 5

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LASER RANGE FINDERS

The present invention relates to laser range finders.

Laser range finders have been used over the past twenty years or so to determine the distance of a target object from a source object on which the range finder is mounted. A laser source is directed onto the target object and a short laser light pulse emitted. The laser light pulse has a small angle of divergence and so can be directed onto the target object with a reasonably high degree of accuracy. An optical receiver detects the reflection from the target object and, from the time elapsed between transmission and reception, determines the range.

In practice, some of the emitted laser light will pass by, or overspill, the target, due either to beam divergence or poor aiming (this problem being particularly acute when either the platform on which the range finder is mounted or the target object or both are moving), and may be reflected by objects behind the target, back towards the receiver. The receiver indicates when a reflected pulse has been received which exceeds a threshold amplitude. Whilst the reception of spurious reflected signals, termed 'clutter,' can be reduced by restricting the field of view of the receiver to a minimum and accurately aiming the receiver onto the target object some clutter will be generated. A second source of clutter in range detection is that produced by objects sited between the laser source and the target object. Such reflections may be generated

for example by a bird or a telegraph pole. Both types of errors, from background and from foreground objects, can result in incorrect range estimation.

In order to improve the accuracy with which target range can be determined, a number of signal processing techniques are used. For example, it is known to impose a minimum range 'gate' on received signals to eliminate signals generated by reflected pulses from objects within a given minimum range from the laser source. The minimum range gate may be a user defined parameter. A second technique involves the provision of first or last pulse reflection selection in which the operator has the choice of selecting either the first pulse returned or the last pulse returned as being the reflection from the target object. The choice is made prior to ranging by setting a switch position. This first or last pulse criterion may be used in combination with the minimum range gate criterion. A disadvantage of the first or last pulse criteria is that the operator may sometimes make an inappropriate selection. Also, on some occasions, the target object will provide neither the first nor the last pulse reflection if there are objects lying both in front of and behind the target object.

A third technique used for improving the accuracy of laser range finders is that of displaying the ranges for all pulse reflections up to a number limited by the display design or selected by the operator. The operator then selects the appropriate target range from the multiple

displayed returns. It is of course possible for the operator to make an incorrect selection and, in addition, this technique is not compatible with automatic operation of the range finding system.

It is an object of the present invention to overcome or at least mitigate the above disadvantages of conventional laser range finding systems. In particular, it is an object of the present invention to enable the provision of a laser range finding system which reduces the effect of clutter returns on range determination whilst minimising the intervention required from an operator.

According to a first aspect of the present invention there is provided a laser range finding method for determining the range to a chosen target, the method comprising the steps of:

(a) transmitting at least one light pulse in the direction of the chosen target;

(b) receiving a series of reflected light pulses including a light pulse reflected from the target;

(c) converting the received light pulses into a corresponding series of electrical signal pulses;

(d) setting a signal threshold amplitude or amplitudes;

(e) identifying those of the received pulses which exceed said threshold amplitude(s) and discarding the remainder;

(f) selecting a range window and discarding those of the identified pulses which lie outside the window;

(g) defining a condition or set of conditions which enable the level of overspill of a laser light pulse over a target to be classified as either 'high' or 'low';

(h) applying said condition or set of conditions to the remaining pulses to classify the level of overspill; and

(i) if the number of remaining pulses is greater than one, selecting the first of these pulses as the target pulse when the level of overspill is classified as 'high' and selecting the last when the level of overspill is classified as 'low', and if only a single pulse exceeds said threshold level selecting that pulse as the target pulse.

The present invention enables the provision of a fully automated range finding system which requires little or no operator input.

In one embodiment of the invention, said condition or one of said set of conditions defined in step (g) is a type of ammunition to be fired at the chosen target, the portion of the system range in which the target lies, or the relative motion between the target and the laser source. More particularly, one condition defined in step (g) may be that if anti-personnel ammunition is selected for firing at the target the level of overspill is classified as 'high.' An alternative or further condition may be that if anti-vehicle ammunition is selected for firing at the target the level of overspill is classified as 'low' when the range is relatively small and is classified as 'high'

when the range is relatively great.

Preferably, step (d) comprises the steps of measuring the amplitude of the largest signal pulse and setting the threshold amplitude(s) to a predetermined fraction or fractions of the largest amplitude. More preferable, said fraction decreases as the range increases.

Preferably, the range is divided into a number of bands in each of which said fraction is constant, said range window being defined as the farthest band containing an identified signal pulse. The range may be divided into near, mid, and far-range bands and said mid and far-range bands encompass relatively great ranges and said near-range band encompasses relatively small ranges.

Preferably, the method comprises the steps of defining a pulse duration threshold, corresponding to the largest pulse duration with which reflected target pulses are expected to be received, and eliminating from the selection carried out in step (f) pulses which have a duration in excess of the duration threshold. The threshold duration may increase with increasing pulse amplitude.

According to a second aspect of the present invention there is provided a laser range finding system for use on an armoured fighting vehicle having a fire control computer, the system comprising:

a laser light source arranged to be directed at a chosen target;

a detector for detecting laser light reflected from objects within the system's field of view;

a signal discriminator comprising input means for receiving signal pulses corresponding to detected light pulses, and signal processing means for automatically identifying those signal pulses which exceed a threshold amplitude and which lie within a predefined range window; and

signal processing means coupled to the fire control computer for receiving therefrom ammunition data,

wherein in use, if the number of identified pulses is greater than one, the signal discriminator is arranged to select as the target reflected pulse the last identified pulse when anti-vehicle ammunition is selected for firing and to select the first identified pulse when anti-personnel ammunition is selected for firing, and if only a single pulse is identified the signal discriminator is arranged to select that pulse as the target reflected pulse.

According to a third aspect of the present invention there is provided an armoured fighting vehicle comprising a laser range finding system as set out above.

For a better understanding of the present invention and in order to show how the same may be carried into effect reference will now be made, by way of example, to the accompanying drawings in which:

Figure 1 illustrates schematically the operation of a laser range finding system;

Figure 2 shows a typical output signal produced by a receiver of the system of Figure 1;

Figure 3 shows in schematic form a signal processing system for identifying a target reflected pulse from a series of reflected pulses;

Figure 4 is a flow diagram illustrating the operation of the system of Figure 3; and

Figure 5 is a flow diagram illustrating a refinement which may be made to the system of Figure 3.

Figure 1 illustrates how a laser light pulse may be used to determine the displacement (indicated by the dotted line) between a pair of objects 1 and 2, the laser source being located on the source object 1. A part of the pulse which is incident on the target object 2 will be reflected back towards the source object 1 (the reflected beam not being shown in Figure 1) where it is received by a photo-detector mounted on the source object 1. The pulse reflected from the target object will diverge, to a similar or greater extent than the transmitted beam, so that only a fraction of the reflected light will be received by the photo-detector. As discussed above, light will also be reflected from objects 5 in the foreground and objects 4 in the background (if the beam overspills the target) giving rise to clutter in the signal generated by the photo-detector.

Figure 2 illustrates a typical output signal from a laser range finding photo-detector during a time window commencing at a time t_1, corresponding to the time of transmission of the laser light pulse, and terminating at a time t_2. The termination time t_2 may be determined by the

maximum range of the system (i.e. the system range). A number of reflected pulses are received by the receiver during the time window including pulses due to noise 6, near objects 7, far objects 9, and the target object itself 8.

An important contribution to background noise in any laser range finding system is the reflection of the transmitted, and reflected, laser pulse from the atmosphere, e.g. air, rain drops etc. In the time after transmission of a laser pulse the contribution of this 'atmospheric' noise tends to fall as, with increasing distance from the laser source, reflected light tends to be increasingly scattered. Thus, it is possible to compensate a received signal for atmospheric noise by increasing the gain of the receiver with time after pulse transmission (alternatively the threshold levels at which received pulses are recorded may be reduced with time). The increase may be in the form of a ramp or may increase to the second power of time (to take account of the divergence of the laser pulse). The received pulse shown in Figure 2 makes use of a ramped gain 10 of constant gradient (shown dotted). The gain shown in Figure 2 levels off after a given time t_1 equivalent to a range of approximately 2500 meters. This is because above 2500m, atmospheric reflections become negligible and contribute little to a reflected pulse received by the range finding system.

The range finding system described hereinbelow relies

upon the classification of chosen targets into two classes. The first class consists of those targets over which a light pulse, transmitted by a laser range finding system, can be expected to 'spill' to a significant extent. For these targets, the significant amount of light spilling over the target is likely to be reflected from objects situated behind the target so that, following receipt by the system detector of a light pulse reflected from the target, one or more background reflections (e.g. pulse 9 shown in Figure 2) are likely to be received. The range finding system is therefore arranged in principle to select the first received pulse where the chosen target falls into the first class.

The second class of targets consists of those targets over which a transmitted light pulse is unlikely to spill to any significant extent. For these targets, it is highly unlikely that any significant reflected pulses will arise from objects lying behind the chosen target, and that any reflected pulses additional to that from the target will be from foreground objects only (e.g. pulse 7 shown in Figure 2). Thus, for targets falling into the second category, the range finding system is arranged in principle to select the last received reflected pulse.

The system shown in Figure 3 is suitable for use on an armoured fighting vehicle and is arranged to operate in accordance with the principles outlined above and comprises a front-end amplifier 11 which receives an electrical input signal 12 provided by a photo-detector (not shown in Figure

3) of the range-finding system. The amplifier 11 applies the ramped gain function 10, shown in Figure 2, to the input signal 12 to compensate for atmospheric reflections. The amplified signal is then applied in parallel to a number $\bar{n}$ of threshold detectors 13_1 to 13n which effectively digitise the amplified signal. The threshold levels τ for the threshold detectors are set in ascending order so that $\tau_n > \tau_{n-1} > \ldots > \tau_2 > \tau_1$.

The outputs from the threshold detectors 13 are applied to 'trigger' inputs of respective time stores 14_1 to 14_n. Each of the time stores receives a time input provided by a clock 15 and is arranged such that, when the corresponding threshold detector 13 is triggered, the current time is latched into the time store. A microprocessor 16 is coupled to each of the time stores to allow the data stored therein to be downloaded into the microprocessor and processed at the end of a pulse reception operation.

Upon transmission of a light pulse by the laser source of the range finding system, a zero reset signal 17 is transmitted to the clock 15. Simultaneously, the reset signal 17 is transmitted to each of the time stores 14 to erase the data stored therein and is also transmitted to the threshold detectors to cause them to be turned on. Thereafter, signals provided by the system photo-detector are coupled through the ramped gain amplifier 11 to the threshold detectors 13. Upon receipt of a reflected pulse, those threshold detectors 13 for which the corresponding

threshold level τ is exceeded by the output of the ramped gain amplifier 11 will be triggered, causing a trigger signal to be issued to the respective time stores 14. The time of receipt of the pulse by the system will be latched into the or each triggered time store. This process is repeated for each received reflected pulse such that, at the end of the receive time window (i.e. t_1 to t_2), all pulse receipt times are stored in one or more of the time stores 14. With reference to the series of reflected pulses shown in Figure 2 for example, the time of receipt of pulse 6 would be stored only in store 14, the time of receipt of pulse 7 would be store in stores 14_1 to 14_4, the time of receipt of pulse 8 would be stored in stores 14_1 to 14_6, and the time of receipt of pulse 9 would be stored in stores 14_1 to 14_3.

At the end of the receive time window, the microprocessor 16 processes the pulse receipt data stored in the time stores to identify that pulse which corresponds to the pulse reflected from the chosen target. The main steps involved in this signal processing operation are shown in Figure 4. The microprocessor 16 firstly interrogates each of the time stores 14 in turn, to obtain therefrom the times at which the respective threshold detectors 13 were triggered and the approximate amplitude of the received pulse or pulses. Where two or more threshold detectors 13 were triggered at the same time, the microprocessor selects as the amplitude of the received pulse the highest threshold exceeded. Thus, for the example shown in Figure

2, the amplitudes for pulses 6 to 9 would be determined as τ_1, τ_4, τ_6 and τ_3 respectively.

The microprocessor 16 then searches through the pulse amplitudes to identify the amplitude of the largest received pulse. It then carries out a further search of the pulse amplitudes to identify those pulses which exceed a predetermined fraction of the maximum amplitude. Typically, this fraction is 0.8.

The microprocessor receives an input signal 18 from the vehicle fire control computer (not shown) which identifies the nature of the ammunition to be fired. The two classes of ammunition which can be indicated are anti-personnel or anti-vehicle. If the input from the fire control computer indicates that anti-personnel ammunition has been selected for firing, the microprocessor 16 acts in accordance with the principles outlined above to select as the target reflected pulse the first received pulse which exceeds the 80% threshold level. On the other hand, if the input signal 18 from the fire control computer indicates that the ammunition selected is anti-vehicle, the microprocessor selects the last of the received pulses which exceeds the 80% threshold. From the time of receipt of the selected pulse, the microprocessor then computes the range to the target, i.e. given by the time of receipt multiplied by the velocity of light divided by two.

Whilst the system described with reference to Figures 3 and 4 may be satisfactory in certain circumstances, a more sophisticated system can be used which recognises

that, even for a relatively large target such as a vehicle, overspill of a transmitted light pulse may still be significant when the target is relatively far from the laser source. Therefore, when the microprocessor input signal 18 indicates that anti-vehicle ammunition has been selected for firing, the microprocessor 16 operates to divide the range of the system into three different bands, namely near range, 0 to 1500 meters, mid-range, 1500 to 2500 meters, and far-range, greater than 2500 meters. The underlying principle is that for large targets situated in the near-range, the level of overspill can be expected to be small and therefore the last received pulse should be selected. For large targets in the mid and far-range, the level of overspill can be expected to be great and so the first received pulse is selected.

Once the microprocessor 16 has interrogated the data stores to obtain the amplitude and time of receipt of received pulses, the steps shown in the flow chart of Figure 5 are carried out. The microprocessor is arranged to determine whether or not any pulses, having an amplitude greater than the preselected fraction of the maximum pulse amplitude, have been received from objects lying in the far-range. If so, and because a high level of overspill is expected from targets in the far-range, the first far-range pulse is identified as the target reflected pulse. If no pulses have been identified in the far range, the system looks next at pulses identified in the mid-range. Again, because a high level of overspill is expected from

targets in this range, the first pulse identified in the mid-range is selected as a target reflected pulse. Again, if no pulses are identified in the mid-range, the system looks for pulses in the near range. If several such pulses are identified, then the system selects the last pulse received from the mid-range as the level of overspill in this range is expected to be small.

When anti-personal ammunition is selected, the system considers only a single band, i.e. the entire system range, as the target can at all ranges be assumed to be small.

A further refinement of this system takes account of the fact that, as the range to the chosen target increases, the amplitude of the pulse reflected from the chosen target is likely to become smaller relative to pulses reflected at smaller ranges. Thus, the microprocessor reduces the fractional requirement for pulses in the far-range. Typically, the fraction for identifying pulses in the far-range is reduced to 0.5 of the maximum pulse amplitude whilst remaining at 0.8 for pulses in the near and mid-ranges.

Yet another refinement involves rejecting received pulses which have an excessive duration. Whilst pulses reflected from a chosen target can be expected to be relatively narrow, certain other 'interference' pulses, in particular pulses reflected from clouds of smoke or dust, can be expected to have a much longer duration. Thus, by determining pulse duration, and rejecting pulses of excessive duration it is possible to eliminate this

particular class of clutter. Pulse duration may be determined by measuring the time between a received pulse exceeding a given one of the thresholds τ and falling back below that threshold.

It may be desirable to vary the threshold duration in dependence upon pulse amplitude, i.e. the threshold duration may increase with pulse amplitude. It may also be desirable to reduce the pulse duration threshold, down to some predetermined minimum value, as the range increases.

It will be appreciated that various modifications may be made to the present invention without departing from the scope of the present invention. For example, whilst the embodiments described above are implemented in a combination of hardware and software, the invention may be implemented exclusively in hardware or in software. The range finding system may also be modified to take account of relative motion between the laser source and the chosen target. Where the chosen target is a vehicle moving relative to the source, even at close range a relatively high level of overspill of the laser beam can be expected. Thus, for a moving vehicle, the first received reflected pulse, either from the entire range window or from a selected range band (e.g. near, mid or far), is selected as the target reflected pulse.

Claims

1. A laser range finding method for determining the range to a chosen target, the method comprising the steps of:

(a) transmitting at least one light pulse in the direction of the chosen target;

(b) receiving a series of reflected light pulses including a light pulse reflected from the target;

(c) converting the received light pulses into a corresponding series of electrical signal pulses;

(d) setting a signal threshold amplitude or amplitudes;

(e) identifying those of the received pulses which exceed said threshold amplitude(s) and discarding the remainder;

(f) selecting a range window and discarding those of the identified pulses which lie outside the window;

(g) defining a condition or set of conditions which enable the level of overspill of a laser light pulse over a target to be classified as either 'high' or 'low';

(h) applying said condition or set of conditions to the remaining pulses to classify the level of overspill; and

(i) if the number of remaining pulses is greater than one, selecting the first of these pulses as the target pulse when the level of overspill is classified as 'high' and selecting the last when the level of overspill is classified as 'low', and if only a single pulse exceeds

said threshold level selecting that pulse as the target pulse.

2. A method according to claim 1, wherein said condition or one of said set of conditions defined in step (g) is a type of ammunition to be fired at the chosen target, the portion of the system range in which the target lies, or the relative motion between the target and the laser source.

3. A method according to claim 2, wherein one condition defined in step (g) is that if anti-personnel ammunition is selected for firing at the target the level of overspill is classified as 'high.'

4. A method according to claim 2 or 3, wherein one condition defined in step (g) is that if anti-vehicle ammunition is selected for firing at the target the level of overspill is classified as 'low' when the range is relatively small and is classified as 'high' when the range is relatively great.

5. A method according to any one of the of the preceding claims, wherein step (d) comprises the steps of measuring the amplitude of the largest signal pulse and setting the threshold amplitude(s) to a predetermined fraction or fractions of the largest amplitude.

6. A method according to claim 5, wherein said fraction decreases as the range increases.

7. A method according to claim 6, wherein the range is divided into a number of bands in each of which said fraction is constant, said range window being defined as the farthest band containing an identified signal pulse.

8. A method according to claim 7 when appended to claim 4, wherein the range is divided into near, mid, and far-range bands and said mid and far-range bands encompass relatively great ranges and said near-range band encompasses relatively small ranges.

9. A method according to any one of the preceding claims and comprising the steps of defining a pulse duration threshold, corresponding to the largest pulse duration with which reflected target pulses are expected to be received, and eliminating from the selection carried out in step (f) pulses which have a duration in excess of the duration threshold.

10. A method according to claim 9, wherein the pulse duration threshold increases with increasing pulse amplitude.

11. A method according to claim 9 or 10, wherein the pulse duration threshold decreases with increasing range to some

predetermined minimum value.

12. A laser range finding system for use on an armoured fighting vehicle having a fire control computer, the system comprising:

a laser light source arranged to be directed at a chosen target;

a detector for detecting laser light reflected from objects within the system's field of view;

a signal discriminator comprising input means for receiving signal pulses corresponding to detected light pulses, and signal processing means for automatically identifying those signal pulses which exceed a threshold amplitude and which lie within a predefined range window; and

signal processing means coupled to the fire control computer for receiving therefrom ammunition data;

wherein in use, if the number of identified pulses is greater than one, the signal discriminator is arranged to select as the target reflected pulse the last identified pulse when anti-vehicle ammunition is selected for firing and to select the first identified pulse when anti-personnel ammunition is selected for firing, and if only a single pulse is identified the signal discriminator is arranged to select that pulse as the target reflected pulse.

13. An armoured fighting vehicle comprising a laser range

finding system according to claim 12.

14. A laser range finding method substantially as hereinbefore described with reference to Figures 1 to 4 of the accompanying drawings or those Figures as modified by Figure 5.

15. A laser range finding system substantially as hereinbefore described with reference to Figures 1 to 4 of the accompanying drawings or those Figures as modified by Figure 5.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number

9526679.7

Relevant Technical fields

(i) UK Cl (Edition 0) H4D (DSPB, DSPU, DLAB, DLRC, DLRG & DLSX)

(ii) Int Cl (Edition 6) G01S, 7/487

Search Examiner

K LONG

Databases (see over)

(i) UK Patent Office

(ii)

NONE

Date of Search

15.4.96

Documents considered relevant following a search in respect of claims 1 to 15

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A	GB 2277219A (LORAL)	-
A	GB 2161340A (MESSERSCTMITT)	-
A	GB 1571043 (ASEA)	-